Morphological and Thermal Characteristics of Winter Nests of the Meadow Vole, *Microtus Pennsylvanicus*

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INTRODUCTION

Mammals have evolved three distinct methods of surviving winter: one method is to migrate to a warmer climate, a second is to hibernate, and the third is to remain both winter active and to develop either physiological, or morphological or behavioural adaptations to cope with winter conditions. The meadow vole, *Microtus pennsylvanicus,* is an example of such a winter-active mammal.

The meadow vole lives in a system of surface runways and underground burrows, often nesting in the burrows during the summer. In winter, the meadow vole usually places its roughly spherical grass nest on the surface as long as there is snow cover (Whitaker, 1980). Wunder (1985) states that the meadow vole must allocate enough energy towards thermoregulation to maintain a constant body temperature of 38.4°C, and that energy allocated to one function generally cannot be used for another. Winter temperatures add an extra energy demand on the vole as it strives to maintain a constant body temperature. The nest of the vole provides an insulative barrier that reduces the amount of heat loss by the vole to the environment.

Our research group has observed high mortality rates in meadow voles owing to conditions of wet snow and rain that alternated with extreme cold when the snow pack is shallow. It was noted that in all cases of mortality the nesting material was saturated.

The present work was an attempt to expand on our previous research (Kalliomaki,1985 and Hillis, 1988) by examining some of the morphological characteristics of meadow vole nests such as: 1. the study of nesting material length and how it changes over a period of time; 2. a study of heat loss through a dry, a humid, and a saturated nest built by 1, 2 or 3 voles; 3. to establish a relationship between nests built in a controlled environment and nests built under an established snow cover.

METHODS

Caged voles at a density of 1, 2, and 3 voles, respectively, were provided with dry grass *ad libitum* as nest-building material for a period of three days. The effects of time on the type of nest produced was determined by collecting the nest either after 3 days, or 7 days or 16 days and measuring the length of fifty randomly-collected pieces of grass from various areas of the nest.

The thermal characteristics of the nests were obtained as follows: a surrogate vole was constructed by skinning a dead vole and replacing the body with a rubber balloon. Two lengths of latex tubing and a thermocouple were sealed into the mouth of the balloon with silicone cement. Water was

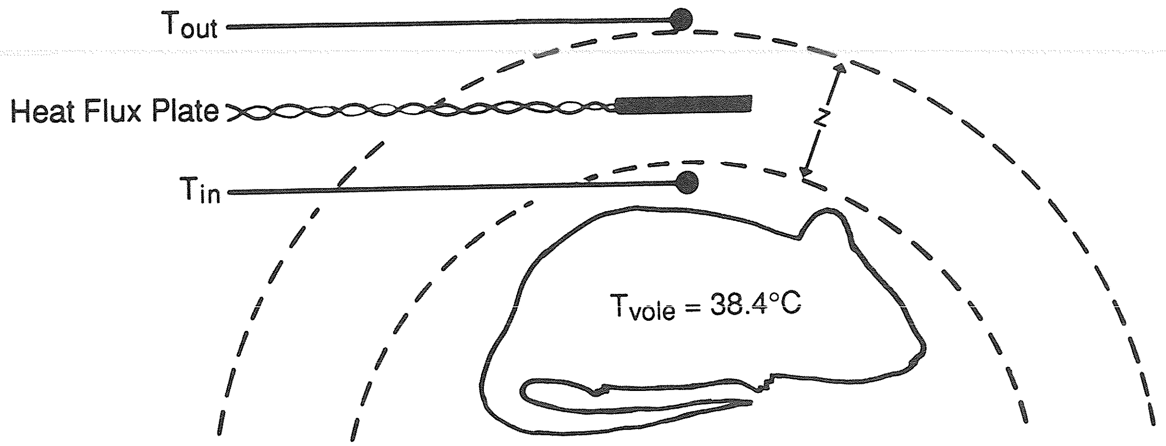

Fig. 1. Schematic to show the method of measurement of thermal conductivity of meadow vole nests. A heat flux plate was inserted into the wall of the nest equidistance from the inner surface and the outer surface of the nest. The temperature gradient was measured with two 22-gauge copper-constantan thermocouples; one was placed on the outer surface (T_{out}) of the nest and the other the inner surface (T_{in}) of the nest, above and below the flux plate. The distance (z) between the two thermocouples was measured. The surrogate vole's core temperature (T_{vole}) was kept at 38.4 ± 1°C.

circulated through the balloon via the tubing at the core temperature of a live vole (38.4°C) and the thermocouple used to monitor the temperature inside the balloon.

The surrogate vole was placed inside a nest with the ambient air temperature outside the nest at 0°C. The inputs from all required sensors were recorded using a Campbell 21X datalogger. Thermal conductivity and cooling rate were determined for nests built by 1, 2, and 3 voles, respectively under both dry and humid conditions. Thermal conductivity was calculated using a form of the Fourier heat-transfer equation:

$$Q = -k' \, dT/dz$$

where Q = heat flux (mv), k' = thermal conductivity (W/m/K), and dT/dz = mean temperature gradient (K/m). The sensor placement are shown in Fig. 1.

Three cages which contained 1, 2, and 3 voles, respectively, were prepared by inserting the maximum amount of grass possible through the cage bars. The cages were placed at ground level under an established snowpack for a period of three days. The thermal conductivity of each nest under humid and saturated conditions was determined as previously described.

RESULTS

A two-way analysis of variance showed that there was no interaction between time (3 days under snow; 7 days and 16 days under controlled conditions) and density (1, 2, and 3 voles) with respect to grass length of the nesting material. A one-way analysis of variance showed that there was a significant difference between grass length with respect to meadow vole numbers per nest and between grass length with respect to number of days given to build the nest. The mean grass length of nesting material was greatest for a nest built by 1 vole over three days under the snow and was shortest in a nest built by 3 voles under the same conditions (Fig. 2). The same trend was observed for nests built in 7 days and 16 days under controlled conditions.

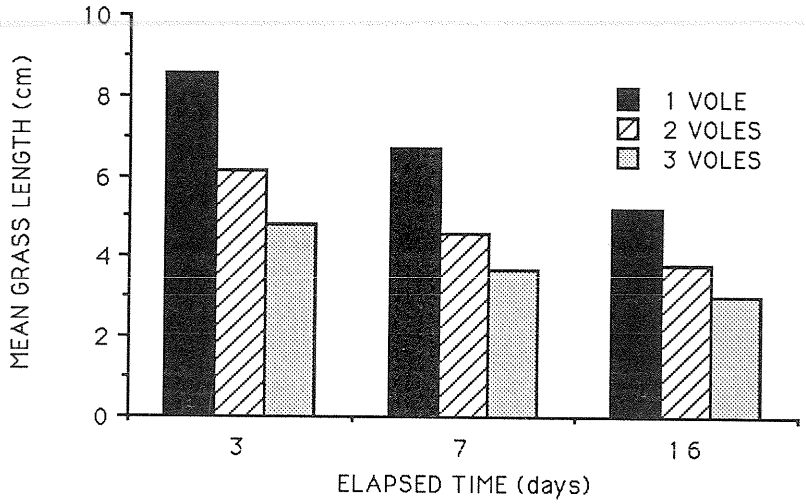

Fig. 2. Changes in mean grass length over time (days) with respect to the number of female meadow voles involved in the nest construction.

The thermal conductivity varied from 0.053 W/m/K to 0.07 W/m/K. No pattern may be deduced from the data either with respect to number of voles or the condition of the nesting material (dry or humid)(Fig. 3).

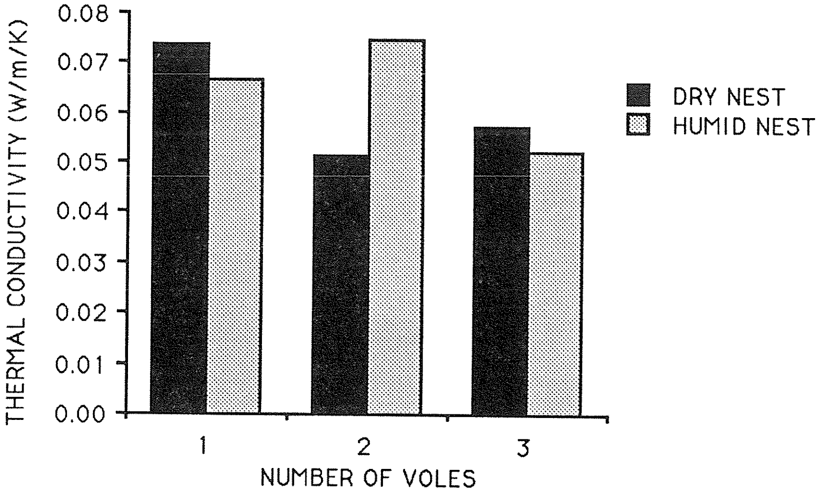

Fig. 3. Changes in mean thermal conductivity (W/m/K) with respect to both a dry nest and a humid nest in a controlled environment.

A relationship exists between the number of voles involved in the construction of the nest and the amount of time it takes the inner nest to cool. For both dry and humid nests the trend was towards an increased rate of cooling with an increase in vole numbers (Fig. 4). The slight decrease in cooling rate for 3 voles cannot be explained.

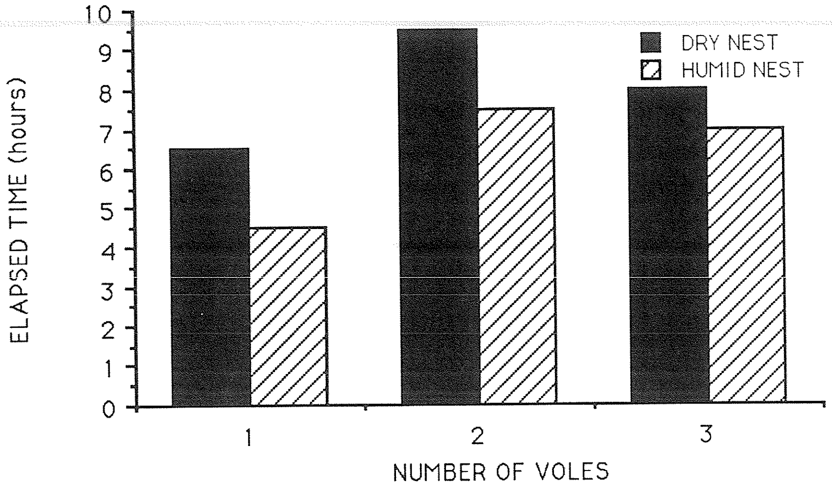

Fig. 4. Elapsed time to reach ambient air temperature for the surrogate vole core which was initially at 38.4°C with the heating source turned off. Solid bars = dry vole in a dry nest; hatched bars = dry vole in a humid nest.

The thermal conductivity value of a nest built by 3 voles in seven days in a controlled environment increased as the nest and the fur of the surrogate vole got wetter (Fig. 5). The thermal conductivity of a nest built in the snow in 3 days by 3 voles also increased as the nest and as the fur of the surrogate vole got wetter (Fig. 5). The dry surrogate vole in a dry nest took 14 hours to reach ambient cooler temperature. But within a wet nest the surrogate vole reached ambient temperature within 2 hours.

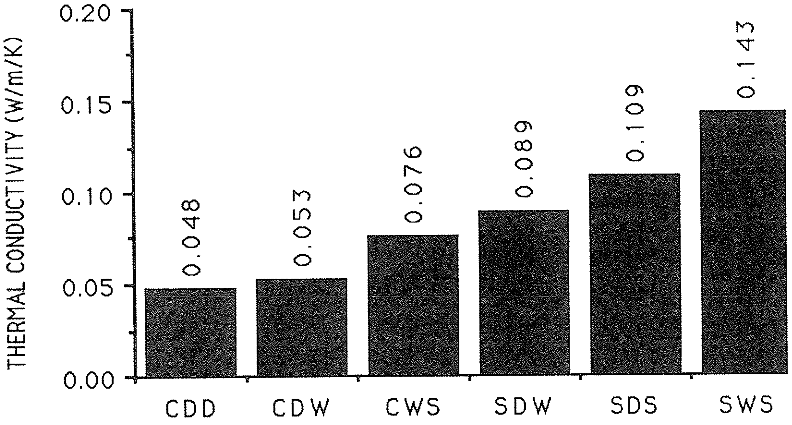

Fig. 5. Changes in mean thermal conductivity (W/m/K) of a nest built by 3 voles in seven days in a controlled environment and a nest built by 3 voles in 3 days under an established snow pack. CDD: controlled chamber; dry fur and dry nest; CDW: controlled chamber; dry fur and saturated nest; CWS: controlled chamber; wet fur and saturated nest; SDW: snow nest; dry fur and humid nest; SDS: snow nest; dry fur and saturated nest; SWS: snow nest; wet fur and saturated nest

DISCUSSION

It was observed that there was a pattern to the distribution of grass lengths used to form the nest. The longer nesting material formed the dome and the shorter, finer material formed the walls and the foundation of the nest. In most cases all the grass presented to the voles was cut and the excess littered the bottom of the cage. This length distribution suggests that there is an optimal grass length and an optimal amount of grass used to build a nest. There is a logarithmic relationship between grass length and time which demonstrates that the collected grass is quickly cut, then, over time, it is slowly modified to a desired length. The slope of the curves show that a nest built by 3 voles is more quickly comminuted than a nest built by 1 vole. These curves could signify that the chances of voles surviving a lethal drop in temperature when there is no snow cover increases with the number of voles involved in the construction of the nest.

The condition of the nest also plays a role in the nest's capacity to retain heat. If the nest is not completely saturated it still provides an adequate barrier from the environment and this may be biologically significant to the meadow vole. Heat loss by the vole to the interior of the nest must play a role in keeping the inner wall of the nest dry. The more voles huddle in the nest, the warmer the nest, and the drier the inner wall. This should increase the chances of vole survival during cold, rainy days when there is no snow cover. Stark (1963) studied nests built by Microtus californicus and stated that the inner surface of the nest was much drier than the external surface, the moisture being held in the grass fibres. It appeared that the hygroscopic properties of the nesting material protected the interior from excessive moisture. Stark (1963) also noted that old, abandoned nests were sometimes completely soaked.

When conditions are unfavourable, small mammals find it advantageous to form communal nests. Heat loss by conduction or convection varies in direct proportion to the amount of surface area exposed, huddling reduces the exposed surface area by at least a third, and heat loss, therefore, is reduced by an equal amount (Marchand, 1987). Huddling, therefore, lengthens the cooling period and increases the vole's chances of surviving when both the animal's fur and the nest are wet. When conditions are unfavourable, voles that huddle should have a better chance of survival than a lone vole in a nest built by itself.

I suggest that meadow voles may depend on well insulated nests to help maintain homeothermy. A nest reduces a vole's heat loss to a cold environment. Meadow voles are most vulnerable to death by hypothermia when they are in a saturated nest with no access to a drier area or to drier nesting material. This could explain why others in our laboratory have observed high mortality in their own experimental work.

In conclusion, my results demonstrate that there is a significant difference between the length of the nesting material used in the construction of the nest with respect to the number of voles involved in the building of the nest and the time given to build the nest. On the surface there seems to be no difference in thermal conductivity values between the nests but it should be stated that thermal conductivity values are relative, and not absolute, values because one cannot be sure of perfect contact between the nesting material and the heat flux plate. The differences in cooling rate emphasis the importance as to whether the nesting material is saturated or dry. Further work is needed for a complete understanding of how heat is dispersed through the nest and how this heat loss affects the meadow vole.

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